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# BIOCHEMISTRY

THIRD EDITION

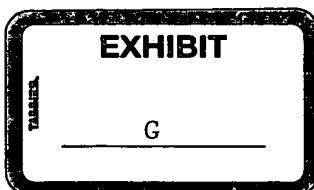


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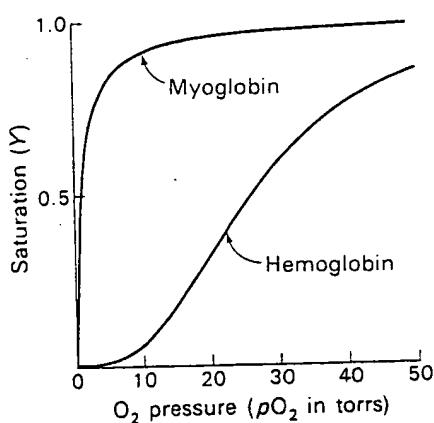
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## HEMOGLOBIN IS AN ALLOSTERIC PROTEIN

The  $\alpha$  and  $\beta$  subunits of hemoglobin have the same structural design as myoglobin. However, new properties of profound biological importance emerge when different subunits come together to form a tetramer. Hemoglobin is a much more intricate and sentient molecule than is myoglobin. Hemoglobin transports  $H^+$  and  $CO_2$  in addition to  $O_2$ . Furthermore, the oxygen-binding properties of hemoglobin are regulated by interactions between separate, nonadjacent sites. Hemoglobin is an allosteric protein, whereas myoglobin is not. This difference is expressed in three ways:

1. The binding of  $O_2$  to hemoglobin enhances the binding of additional  $O_2$  to the same hemoglobin molecule. In other words,  $O_2$  binds cooperatively to hemoglobin. In contrast, the binding of  $O_2$  to myoglobin is not cooperative.
2. The affinity of hemoglobin for oxygen depends on pH, whereas that of myoglobin is independent of pH. The  $CO_2$  molecule also affects the oxygen-binding characteristics of hemoglobin.
3. The oxygen affinity of hemoglobin is further regulated by organic phosphates such as 2,3-bisphosphoglycerate (BPG). The result is that hemoglobin has a lower affinity for oxygen than does myoglobin.

**Torr—**  
A unit of pressure equal to that exerted by a column of mercury 1 mm high at  $0^\circ C$  and standard gravity (1 mm Hg).  
Named after Evangelista Torricelli (1608–1647), the inventor of the mercury barometer.

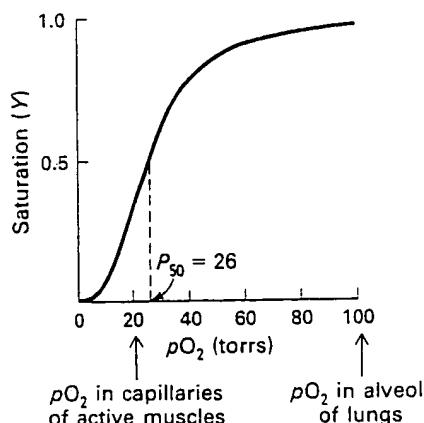


**Figure 7-21**  
Oxygen dissociation curves of myoglobin and hemoglobin. Saturation of the oxygen-binding sites is plotted as a function of the partial pressure of oxygen surrounding the solution.

## OXYGEN BINDS COOPERATIVELY TO HEMOGLOBIN

The saturation  $Y$  is defined as the fractional occupancy of the oxygen-binding sites. The value of  $Y$  can range from 0 (all sites empty) to 1 (all sites filled). A plot of  $Y$  versus  $pO_2$ , the partial pressure of oxygen, is called an *oxygen dissociation curve*. The oxygen dissociation curves of myoglobin and hemoglobin differ in two ways (Figures 7-21 and 7-22). For any given  $pO_2$ ,  $Y$  is higher for myoglobin than for hemoglobin. This means that *myoglobin has a higher affinity for oxygen than does hemoglobin*. Oxygen affinity can be characterized by a quantity called  $P_{50}$ , which is the partial pressure of oxygen at which 50% of sites are filled (i.e., at which  $Y = 0.5$ ). For myoglobin,  $P_{50}$  is typically 1 torr, whereas for hemoglobin,  $P_{50}$  is 26 torrs.

The second difference is that the *oxygen dissociation curve of myoglobin is hyperbolic, whereas that of hemoglobin is sigmoidal*. Let us consider these curves in quantitative terms, starting with the one for myoglobin be-



**Figure 7-22**  
Oxygen dissociation curve of hemoglobin. Typical values for  $pO_2$  in the capillaries of active muscle and in the alveoli of the lung are marked on the horizontal axis. Note that  $P_{50}$  for hemoglobin under physiological conditions lies between these values.